분할기반의 선형 호 보간법에 의한 RSSI기반의 위치 인식

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RSSI-based Location Determination via Segmentation-based Linear Spline Interpolation Method

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요 약

RSSI 방법에 의한 모바일 사용자의 위치확인은 최근에 매우 주목을 받는 연구영역이지만, 모바일사용자에 의해 쉽게 변화하는 RSSI의 신호전파특성의 복잡성 때문에 여전히 문제가 많은 부분으로 남아있다. 따라서 본 연구에서는 분할기반의 선형 보간법이 이러한 복잡한 환경에서의 무선신호의 활발한 변화패턴을 안정시키기 위해 제안되었다. 제안된 최적화 알고리즘은 IEEE802.15.4 표준에서 운영되는 현재의 무선 위치인식(CC2431, 칩콘사, 노르웨이) 알고리즘에 추가의 형태로 제안되었다. 첫단계는 다른 정적 위치에서의 RSSI값이 모아지고 정해진 거리에 대한 평균값과 표준편차를 얻기 위한 단계를 거치는 캘리브레이션 모델로 구성된다. RSSI 평탄화알고리즘은 사용자가 움직일 때 각 레퍼런스노드에서 받는 무선신호의 동적변동을 최소화하기 위해 제안되었다. 거리는 첫 번째 단계에서 얻어지는 분할공식을 사용하여 계산되어진다. RSSI값이 하나의 분할보다 크게 떨어지는 경우에는, 확률적 접근방법에 의해서 그 거리가 결정된다. 각 거리에 대한 거리확률분포함수가 계산되고 특별한 RSSI에서 가장 높은 함수값이 거리로 결정되게 된다. 마지막으로 각 레퍼런스 노드로부터 얻어진 거리를 사용하여 삼각측량 알고리즘이 사용되어서 위치 가 결정되게 된다. 실험 결과 제안된 알고리즘에 의해 계산된 위치는 위치추적을 위한 알고리즘으로 매우 가능성있는 결과를 제시하였다.

ABSTRACT

Location determination of mobile user via RSSI approach has received ample attention from researchers lately. However, it remains a challenging issue due to the complexities of RSSI signal propagation characteristics, which are easily exacerbated by the mobility of user. Hence, a segmentation-based linear spline interpolation method is proposed to cater for the dynamic fluctuation pattern of radio signal in complex environment. This optimization algorithm is proposed in addition to the current radiolocation's (CC2431, Chipcon, Norway) algorithm, which runs on IEEE802.15.4 standard. The enhancement algorithm involves four phases. First phase consists of calibration model in which RSSI values at different static locations are collected and processed to obtain the mean and standard deviation value for the predefined distance. RSSI smoothing algorithm is proposed to minimize the dynamic fluctuation of radio signal received from each reference node when the user is moving. Distances are computed using the segmentation formula obtain in the first phase. In situation where RSSI value falls in more than one segment, the ambiguity of distance is solved by probability approach. The distance probability distribution function(pdf) for each distances are computed and distance with the highest pdf at a particular RSSI is the estimated distance. Finally, with the distances obtained from each reference node, an iterative trilateration algorithm is used for position estimation. Experiment results obtained position the proposed algorithm as a viable alternative for location tracking.

Keyword

Location Tracking, RSSI, Refinement Algorithm, Segmentation, Probability Distribution Function

I. INTRODUCTION

Maturity in the development of wireless technology has perked up a growing interest for researcher in location tracking sector. Many approaches have been proposed to cater for the best tracking solution. RSSI technique is among the popular approach due to its simplicity and its ability to perform in both indoor and outdoor environment. However, irrespective of whether the issue of interest is that of target detection, classification, or tracking, solution of the problem is complicated by the non-stationary character of the received signal strength. The causes of this non-stationarity include motion of the mobile target and variations in environmental conditions.

Therefore, to deal with this complication, we resort to the use of this segmentation-based linear spline interpolation algorithm (SLSIA).

II. SEGMENTATION-BASED LINEAR SPLINE INTERPOLATION ALGORITHM

The accuracy refinement algorithm proposed combines RSSI smoothing algorithm with probabilistic method for segmentation-based distance estimation. The purpose of this segmentation is due to the fact that, in real world scenario, the relationship between RSSI signal strength and distance is not straightforward and RSSI tends to fluctuate out of certain region (Figure 1).

Therefore, instead of obtaining a single linear equation for each calibrated signal curve, we have broken the calibrated curves at each reference nodes into several range of segments with their own linear interpolation equation on every segment. This proposed algorithm comprises of four phases, which involve calibration of RSSI for each reference node, RSSI smoothing algorithm, distance estimation and position estimation. The flow of algorithm is shows in Figure 2 and the details of these four phases are described in the following subsections.

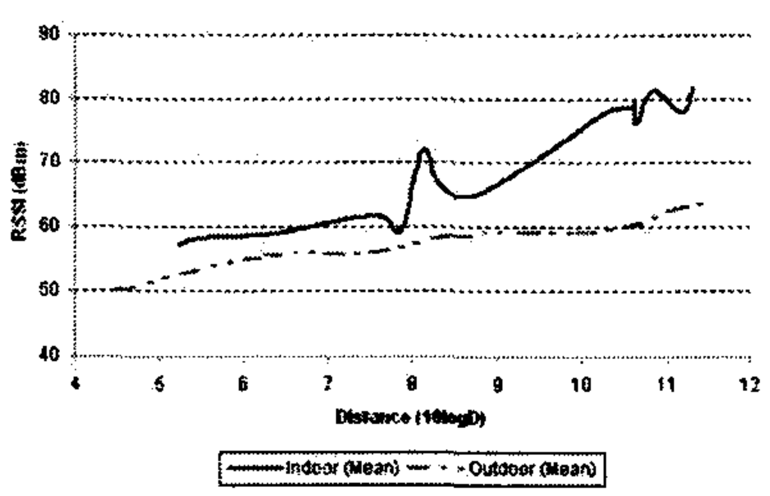

Fig 1. Signal strength behaves differently in different environments. Signal strength does not correlate with distance in indoor environment.

A. Calibration Phase

In this step, the mean and standard deviation of signal strength reading collected at several predefined distances from the respective reference node is recorded. The curve pattern is approximated or modeled using linear spline interpolation [2], in which the curve is segmented into several linear curves (Figure 3). If x represents the logarithm of distance (10log10D) and y represents the RSSI value, for a value of y that falls within the segment range , the corresponding value of y can be calculated by (1).

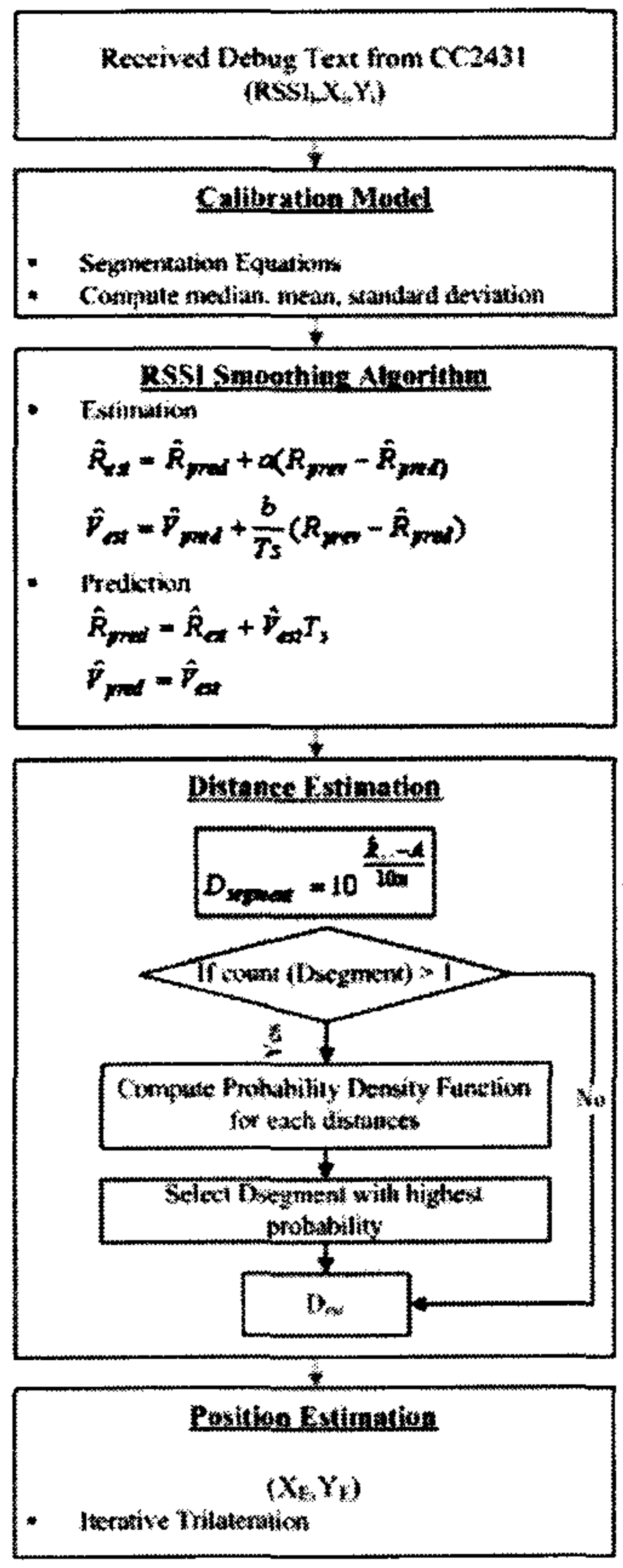

Fig 2. Segmentation-based Linear Spline Interpolation Algorithm.

$$\frac{y - y_0}{y_1 - y_0} = \frac{x - x_0}{x_1 - x_o} \tag{1}$$

If x does not lie between the total range, i.e. $x_3 \notin [x_1, x_2]$, the value of the point can be obtained by using extrapolation method.

A set of standard deviation, median and mean value are computed to classify the calibrated RSSI into segments. An algorithm is designed to identify which segment of the filtered RSSI can possibly lies in. Distance is computed by solving the linear interpolation equation of that segment.

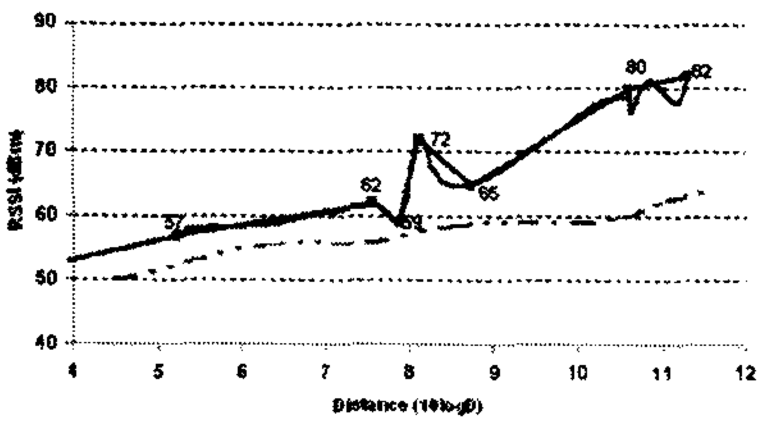

Figure 3. Segmented RSSI curve.

B. RSSI Smoothing Algorithm

Smoothing algorithm is proposed to minimize the dynamic fluctuation of radio signal received from each reference node when the user is moving. There is a correlation between current positions with previous location. The selection of gains is based on the optimal trade-off between the filter coefficients and the blind node's motion change rate, so that the noise is reduced to an optimal value. The basic assumption for this smoothing algorithm is that the constant velocity motion will result in constant data change rate and stationary noise processes.

The estimation and prediction stages for the smoothing algorithm used are shown as below:

Estimation:

$$\hat{R}_{est(i)} = \hat{R}_{pred(i)} + a\left(R_{prev(i)} - \hat{R}_{pred(i)}\right) \quad (2)$$

$$\hat{V}_{est(i)} = \hat{V}_{pred(i)} + \frac{b}{T_s}\left(R_{prev(i)} - \hat{R}_{pred(i)}\right) \quad (3)$$

Prediction:

$$\hat{R}_{pred(i+1)} = \hat{R}_{est(i)} + \hat{V}_{est(i)} T_s \quad (4)$$

$$\hat{V}_{pred(i+1)} = \hat{V}_{est(i)} \quad (5)$$

where

$\hat{R}_{est(i)}$ = the ith smoothed estimate range,

$\hat{R}_{pred(i)}$ = the ith predicted range,

$R_{prev(i)}$ = the ith measured range,

$\hat{V}_{est(i)}$ = the ith smoothed estimate range rate,

$\hat{V}_{pred(i)}$ = the ith predicted range rate,

a, b = gain constants,

Ts = time segment upon the ith update.

C. Distance Estimation

Since the calibrated curve is not a linear curve, sometimes, the RSSI received may falls in more than one segment, which may results in getting more than one distance. For that reason, a probabilistic approach is proposed to solve the ambiguity of distance computation and select the best possible distance.

Probabilistic approach is proposed as the RSSI react as a log-normal distribution towards the distance. Equation (6) shows the RSSI to distance equation expressed in dBm,

$$RSSI = 10n\log_{10} D + A \quad (6)$$

where n is the signal propagation constant, D is the distance from sender and A is the RSSI at 1 meter distance. When signal strength is approximated by the inverse power law, the received signal uncertainty is usually approximated by a log-Normal distribution function as followed:

$$\frac{\exp-(s^2/\sigma^2)}{\sqrt{(2\pi\sigma^2)}} \quad (7)$$

where s is the filtered RSSI and sigma is the standard deviation of the log-Normal distribution in dBm. Therefore, by combining equation (6) and (7), we obtained (8) for probability distribution function (PDF) calculation.

$$\frac{\exp-((-10n\log_{10} D + A - RSSI_i)^2/\sigma^2)}{D\sqrt{2\pi\sigma^2}} \quad (8)$$

Distance with the highest PDF value is the estimated distance for that time segment.

This two-dimensional PDF describes how likely the mobile station is to be found at a particular coordinate given the radio signal information obtained between the mobile and the particular reference node. The mean and standard deviation represents the characteristics of the distribution

D. Position Estimation

Trilateration is a method to determine the position of an object based on simultaneous range measurements from three reference nodes at known location. Iterative method is applied to derive blind node position according to the estimated distance resolved from filtered RSSI and the calibrated constant. The algorithm requires the coordinates of at least three reference nodes

(x_i, y_i) and the distances di between the blind node and the respective reference nodes, which are estimated in the previous subsection. A trivial estimated position (x_e, y_e) is needed to start the algorithm. This estimated position represents the latest calculated position. By applying the first degree Taylor series approximation, the adjustment (Δx, Δy) used in iteration of (x_e, y_e) can be determined by matrix calculation. By calculating the mean value of the points obtained through the matrix calculation, the final position is computed. Both CC2431 position estimation results and this iterative trilateration algorithm are analyzed to observe the improvement achieved.

III. EXPERIMENTAL RESULTS

To analyze the effectiveness of the proposed algorithms, experiments were conducted in a hybrid indoor and outdoor environment (34mx30m). TIP sensor node [3] which features Chipcon CC2420 [4] radio for wireless communication is used as a base station to receive raw RSSI values from blind node. The base station is connected to a personal computer with monitoring program via USB serial port. A user carrying the blind node walked from an indoor starting point with coordinate (1.5, 0) to an outdoor ending point with coordinate (1.5, 47.5). The movement was tracked at real-time with an interval of 1.3 seconds.

Figure 4 reveals a comparison of location coordinates of the proposed algorithms in hybrid indoor and outdoor environment, in which Segmentation-oriented Linear Spline Interpolation yeilds an average error of 1.75m, which are more accurate than the average error of 2.8m obtained from location coordinates provided by CC2431. Table 1 gives a summary of the accuracy comparison for two algorithms. Inspection of the results for each of the test bed described in Table 1 revealed that the performance of SLSIA algorithm produce a better output in accuracy enhancement. The experimental results presented in this report demonstrate the ability of this system to estimate user's location with a high degree of accuracy. The result positions this SLSIA algorithm as a very viable alternative for tracking.

Table 1. Algorithm Comparison.

Algorithm	Average Error
	Hybrid Environment
CC2431	2.80m
SLSIA	1.75m

IV. CONCLUSIONS

Segmentation-based Linear Spline Interpolation algorithm is proposed in viewing of the non-linearity relationship between distance and RSSI in complex

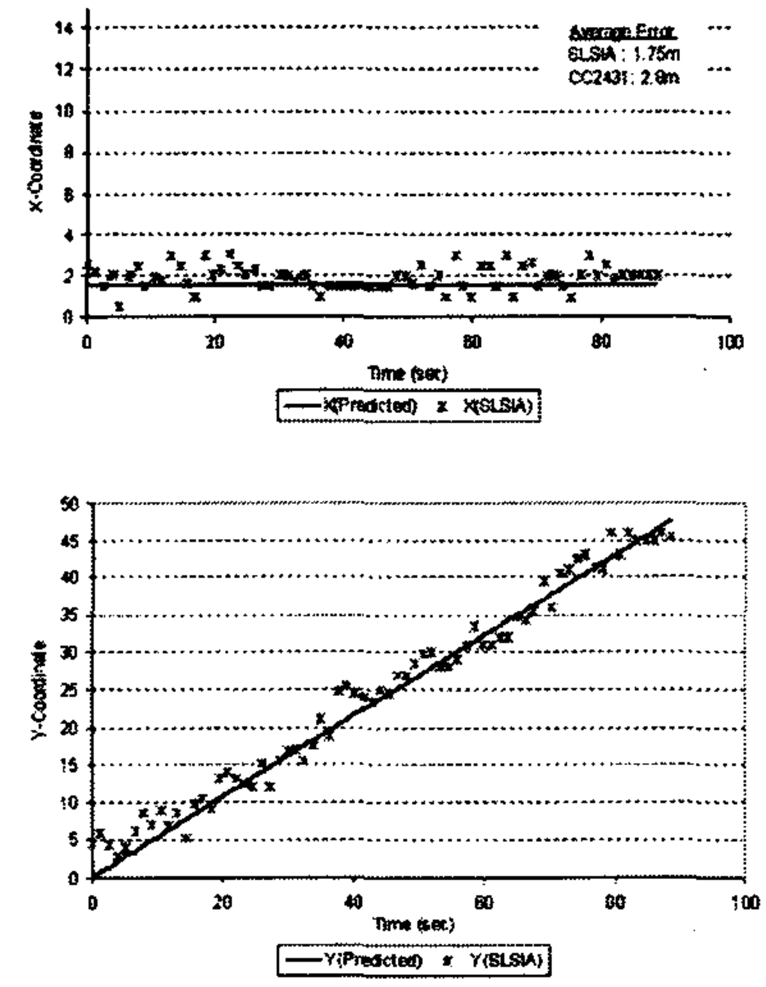

Figure 4. Comparison of location coordinates (X, Y).

environment where signal fluctuation is high. This SLSIA algorithm outperforms the current system's algorithm in terms of accuracy regardless of the types of environment it is to be implemented. Experiment were conducted to show the improvement of the proposed algorithm compared to the current CC2431 location estimation engine. Overall average accuracy is improved through the refining algorithms that combine the segmentation of calibrated signal propagation constants, reduction of dynamic signal fluctuation, probabilistic approach of distance estimation and trilateration.

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